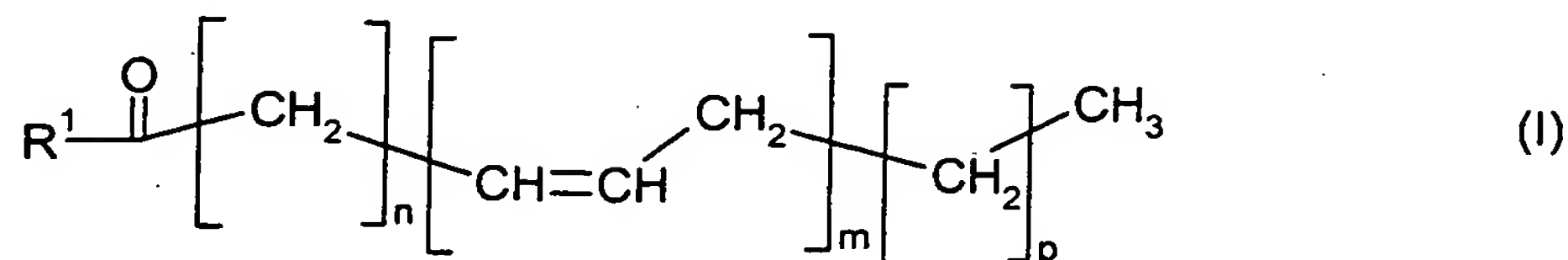


We claim:

1.1. A process for the production of compounds of the formula I

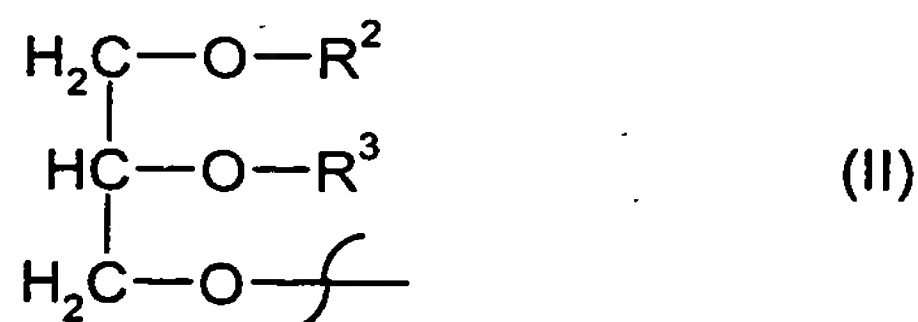


in transgenic organisms with a content of at least 1% by weight of these compounds based on the total lipid content of the transgenic organism, which comprises the following process steps:

- a) introducing, into the organism, at least one nucleic acid sequence which encodes a $\Delta 9$ -elongase or a $\Delta 6$ -desaturase activity, and
- b) introducing, into the organism, at least one nucleic acid sequence which encodes a $\Delta 8$ -desaturase or a $\Delta 6$ -elongase activity, and
- c) introducing, into the organism, at least one nucleic acid sequence which encodes a $\Delta 5$ -desaturase activity, and
- d) introducing, into the organism, at least one nucleic acid sequence which encodes a $\Delta 5$ -elongase activity, and
- e) introducing, into the organism, at least one nucleic acid sequence which encodes a $\Delta 4$ -desaturase activity, and

where the variables and substituents in formula I have the following meanings:

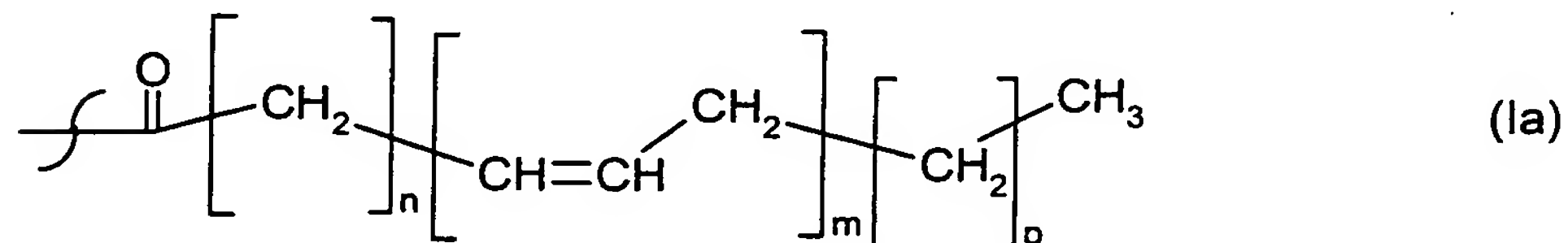
$R^1 =$ hydroxyl, coenzyme A (thioester), lysophosphatidylcholine, lysophosphatidylethanolamine, lysophosphatidylglycerol, lysodiphosphatidylglycerol, lysophosphatidylserine, lysophosphatidylinositol, sphingo base or a radical of the formula II



in which

$R^2 =$ hydrogen, lysophosphatidyl choline, lysophosphatidylethanolamine, lysophosphatidylglycerol, lysodiphosphatidylglycerol, lysophosphatidylserine, lysophosphatidylinositol or saturated or unsaturated C_2 - C_{24} -alkylcarbonyl,

$R^3 =$ hydrogen, saturated or unsaturated C_2 - C_{24} -alkylcarbonyl, or R^2 and R^3 independently of one another are a radical of the formula Ia:



in which

$n = 2, 3, 4, 5, 6, 7$ or 9 , $m = 2, 3, 4, 5$ or 6 and $p = 0$ or 3 .

2. The process according to claim 1, wherein the nucleic acid sequences which encode polypeptides with $\Delta 9$ -elongase, $\Delta 6$ -desaturase, $\Delta 8$ -desaturase, $\Delta 6$ -elongase, $\Delta 5$ -desaturase, $\Delta 5$ -elongase or $\Delta 4$ -desaturase activity are selected from the group consisting of:

- a) a nucleic acid sequence with the sequence shown in SEQ ID NO: 1, SEQ ID NO: 3, SEQ ID NO: 5, SEQ ID NO: 7, SEQ ID NO: 9, SEQ ID NO: 11, SEQ ID NO: 13, SEQ ID NO: 15, SEQ ID NO: 17, SEQ ID NO: 19, SEQ ID NO: 21, SEQ ID NO: 23, SEQ ID NO: 25, SEQ ID NO: 27, SEQ ID NO: 29, SEQ ID NO: 31, SEQ ID NO: 33, SEQ ID NO: 35, SEQ ID NO: 37, SEQ ID NO: 39, SEQ ID NO: 41, SEQ ID NO: 43, SEQ ID NO: 45, SEQ ID NO: 47, SEQ ID NO: 49, SEQ ID NO: 51, SEQ ID NO: 53, SEQ ID NO: 59, SEQ ID NO: 61, SEQ ID NO: 63, SEQ ID NO: 65, SEQ ID NO: 67, SEQ ID NO: 69, SEQ ID NO: 71, SEQ ID NO: 73, SEQ ID NO: 75, SEQ ID NO: 77, SEQ ID NO: 79, SEQ ID NO: 81, SEQ ID NO: 83, SEQ ID NO: 85, SEQ ID NO: 89, SEQ ID NO: 91, SEQ ID NO: 93, SEQ ID NO: 95, SEQ ID NO: 97, SEQ ID NO: 99, SEQ ID NO: 101, SEQ ID NO: 103, SEQ ID NO: 111, SEQ ID NO: 113, SEQ ID NO: 117, SEQ ID NO: 119, SEQ ID NO: 131, SEQ ID NO: 133, SEQ ID NO: 135, SEQ ID NO: 137 or SEQ ID NO: 183, or

- b) nucleic acid sequences which, as the result of the degeneracy of the genetic code, can be derived from the amino acid sequences shown in SEQ ID NO: 2, SEQ ID NO: 4, SEQ ID NO: 6, SEQ ID NO: 8, SEQ ID NO: 10, SEQ ID NO: 12, SEQ ID NO: 14, SEQ ID NO: 16, SEQ ID NO: 18, SEQ ID NO: 20, SEQ ID NO: 22, SEQ ID NO: 24, SEQ ID NO: 26, SEQ ID NO: 28, SEQ ID NO: 30, SEQ ID NO: 32, SEQ ID NO: 34, SEQ ID NO: 36, SEQ ID NO: 38, SEQ ID NO: 40, SEQ ID NO: 42, SEQ ID NO: 44, SEQ ID NO: 46, SEQ ID NO: 48, SEQ ID NO: 50, SEQ ID NO: 52, SEQ ID NO: 54, SEQ ID NO: 60, SEQ ID NO: 62, SEQ ID NO: 64, SEQ ID NO: 66, SEQ ID NO: 68, SEQ ID NO: 70, SEQ ID NO: 72, SEQ ID NO: 74, SEQ ID NO: 76, SEQ ID NO: 78, SEQ ID NO: 80, SEQ ID NO: 82, SEQ ID NO: 84, SEQ ID NO: 86, SEQ ID NO: 88, SEQ ID NO: 92, SEQ ID NO: 94, SEQ ID NO: 96, SEQ ID NO: 98, SEQ ID NO: 100, SEQ ID NO: 102, SEQ ID NO: 104, SEQ ID NO: 112, SEQ ID NO: 114, SEQ ID NO: 118, SEQ ID NO: 120, SEQ ID NO: 132, SEQ ID NO: 134, SEQ ID NO: 136, SEQ ID NO: 138 or SEQ ID NO: 184, or
- c) derivatives of the nucleic acid sequence shown in SEQ ID NO: 1, SEQ ID NO: 3, SEQ ID NO: 5, SEQ ID NO: 7, SEQ ID NO: 9, SEQ ID NO: 11, SEQ ID NO: 13, SEQ ID NO: 15, SEQ ID NO: 17, SEQ ID NO: 19, SEQ ID NO: 21, SEQ ID NO: 23, SEQ ID NO: 25, SEQ ID NO: 27, SEQ ID NO: 29, SEQ ID NO: 31, SEQ ID NO: 33, SEQ ID NO: 35, SEQ ID NO: 37, SEQ ID NO: 39, SEQ ID NO: 41, SEQ ID NO: 43, SEQ ID NO: 45, SEQ ID NO: 47, SEQ ID NO: 49, SEQ ID NO: 51, SEQ ID NO: 53, SEQ ID NO: 59, SEQ ID NO: 61, SEQ ID NO: 63, SEQ ID NO: 65, SEQ ID NO: 67, SEQ ID NO: 69, SEQ ID NO: 71, SEQ ID NO: 73, SEQ ID NO: 75, SEQ ID NO: 77, SEQ ID NO: 79, SEQ ID NO: 81, SEQ ID NO: 83, SEQ ID NO: 85, SEQ ID NO: 89, SEQ ID NO: 91, SEQ ID NO: 93, SEQ ID NO: 95, SEQ ID NO: 97, SEQ ID NO: 99, SEQ ID NO: 101, SEQ ID NO: 103, SEQ ID NO: 111, SEQ ID NO: 113, SEQ ID NO: 117, SEQ ID NO: 119, SEQ ID NO: 131, SEQ ID NO: 133, SEQ ID NO: 135, SEQ ID NO: 137 or SEQ ID NO: 183 which encode polypeptides with at least 40% identity at the amino acid level with SEQ ID NO: 2, SEQ ID NO: 4, SEQ ID NO: 6, SEQ ID NO: 8, SEQ ID NO: 10, SEQ ID NO: 12, SEQ ID NO: 14, SEQ ID NO: 16, SEQ ID NO: 18, SEQ ID NO: 20, SEQ ID NO: 22, SEQ ID NO: 24, SEQ ID NO: 26, SEQ ID NO: 28, SEQ ID NO: 30, SEQ ID NO: 32, SEQ ID NO: 34, SEQ ID NO: 36, SEQ ID NO: 38, SEQ ID NO: 40, SEQ ID NO: 42, SEQ ID NO: 44,

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SEQ ID NO: 46, SEQ ID NO: 48, SEQ ID NO: 50, SEQ ID NO: 52, SEQ ID NO: 54, SEQ ID NO: 60, SEQ ID NO: 62, SEQ ID NO: 64, SEQ ID NO: 66, SEQ ID NO: 68, SEQ ID NO: 70, SEQ ID NO: 72, SEQ ID NO: 74, SEQ ID NO: 76, SEQ ID NO: 78, SEQ ID NO: 80, SEQ ID NO: 82, SEQ ID NO: 84, SEQ ID NO: 86, SEQ ID NO: 88, SEQ ID NO: 92, SEQ ID NO: 94, SEQ ID NO: 96, SEQ ID NO: 98, SEQ ID NO: 100, SEQ ID NO: 102, SEQ ID NO: 104, SEQ ID NO: 112, SEQ ID NO: 114, SEQ ID NO: 118, SEQ ID NO: 120, SEQ ID NO: 132, SEQ ID NO: 134, SEQ ID NO: 136, SEQ ID NO: 138 or SEQ ID NO: 184 and which have $\Delta 9$ -elongase, $\Delta 6$ -desaturase, $\Delta 8$ -desaturase, $\Delta 6$ -elongase, $\Delta 5$ -desaturase, $\Delta 5$ -elongase or $\Delta 4$ -desaturase activity.

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3. The process according to claim 1 or 2, wherein a nucleic acid sequence which encodes polypeptides with $\omega 3$ -desaturase activity, selected from the group consisting of:

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- a) a nucleic acid sequence with the sequence shown in SEQ ID NO: 87 or SEQ ID NO: 105, or
- b) nucleic acid sequences which, as the result of the degeneracy of the genetic code, can be derived from the amino acid sequence shown in SEQ ID NO: 88 or SEQ ID NO: 106, or
- c) derivatives of the nucleic acid sequence shown in SEQ ID NO: 87 or SEQ ID NO: 105 which encodes polypeptides with at least 60% identity at the amino acid level with SEQ ID NO: 88 or SEQ ID NO: 106 and which have $\omega 3$ -desaturase activity

is additionally introduced to the organism.

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4. The process according to any of claims 1 to 3, wherein a nucleic acid sequence which encodes polypeptides with $\Delta 12$ -desaturase activity, selected from the group consisting of:
- a) a nucleic acid sequence with the sequence shown in SEQ ID NO: 107 or SEQ ID NO: 109, or
 - b) nucleic acid sequences which, as the result of the degeneracy of the genetic code, can be derived from the amino acid sequence shown in SEQ ID NO: 108 or SEQ ID NO: 110, or

- c) derivatives of the nucleic acid sequence shown in SEQ ID NO: 107 or SEQ ID NO: 110 which encode polypeptides with at least 60% identity at the amino acid level with SEQ ID NO: 108 or SEQ ID NO: 110 and which have $\Delta 12$ -desaturase activity

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is additionally introduced into the organism.

5. The process according to any of claims 1 to 4, wherein the substituents R^2 or R^3 independently of one another are saturated or unsaturated C_{18} - C_{22} -alkylcarbonyl.
- 10 6. The process according to any of claims 1 to 5, wherein the substituents R^2 or R^3 independently of one another are unsaturated C_{18} -, C_{20} - or C_{22} -alkylcarbonyl with at least two double bonds.
- 15 7. The process according to any of claims 1 to 6, wherein the transgenic organism is a transgenic microorganism or a transgenic plant.
8. The process according to any of claims 1 to 7, wherein the transgenic organism is an oil-producing plant, a vegetable plant or an ornamental.
- 20 9. The process according to any of claims 1 to 8, wherein the transgenic organism is a transgenic plant selected from the group of the plant families:
Adelotheciaceae, Anacardiaceae, Asteraceae, Apiaceae, Betulaceae,
Boraginaceae, Brassicaceae, Bromeliaceae, Caricaceae, Cannabaceae,
25 Convolvulaceae, Chenopodiaceae, Crypthecodiniaceae, Cucurbitaceae,
Ditrichaceae, Elaeagnaceae, Ericaceae, Euphorbiaceae, Fabaceae,
Geraniaceae, Gramineae, Juglandaceae, Lauraceae, Leguminosae, Linaceae
or Prasinophyceae.
- 30 10. The process according to any of claims 1 to 9, wherein the compounds of the formula I are isolated from the organism in the form of their oils, lipids or free fatty acids.
- 35 11. The process according to any of claims 1 to 10, wherein the compounds of the formula I are isolated in a concentration of at least 5% by weight based on the total lipid content of the transgenic organism.
12. The oil, lipid or fatty acid, or a fraction thereof, produced by the process according to any of claims 1 to 11.

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13. The oil, lipid or fatty acid composition which comprises PUFAs produced by a process according to any of claims 1 to 11 and which is derived from transgenic plants.
- 5 14. A process for the production of oils, lipids or fatty acid compositions by mixing oils, lipids or fatty acids according to claim 12 or oil, lipid or fatty acid compositions according to claim 13 with animal oils, lipids or fatty acids.
- 10 15. The use of oils, lipids or fatty acids according to claim 12 or oils, lipid or fatty acid compositions according to claim 13 or oils, lipids or fatty acid compositions produced according to claim 14 in feed, foodstuffs, cosmetics or pharmaceuticals.
- 15 16. An isolated nucleic acid sequence which encodes a polypeptide with $\Delta 5$ -elongase activity and comprises an amino acid sequence selected from the group of an amino acid sequence with the sequence shown in SEQ ID NO: 115, SEQ ID NO: 116, SEQ ID NO: 139, SEQ ID NO: 140, SEQ ID NO: 141 or SEQ ID NO: 142.
- 20 17. The isolated nucleic acid sequence according to claim 16, wherein the nucleic acid sequence which encodes a polypeptide with $\Delta 5$ -elongase activity comprises a combination of the amino acid sequences selected from the group consisting of:
- 25 a)a) SEQ ID NO: 115 and SEQ ID NO: 139, SEQ ID NO: 115 and SEQ ID NO: 140 or SEQ ID NO: 139 and SEQ ID NO: 140; or
- b)b) SEQ ID NO: 116 and SEQ ID NO: 141, SEQ ID NO: 116 and SEQ ID NO: 142 or SEQ ID NO: 141 and SEQ ID NO: 142; or
- c)c) SEQ ID NO: 115, SEQ ID NO: 139 and SEQ ID NO: 140 or SEQ ID NO: 116, SEQ ID NO: 141 and SEQ ID NO: 142.
- 30 18. The isolated nucleic acid sequence according to claim 16 or 17 which encodes a polypeptide with $\Delta 5$ -elongase activity, wherein the nucleic acid sequence is selected from the group consisting of:
- 35 a) a nucleic acid sequence with the sequence shown in SEQ ID NO: 43, SEQ ID NO: 45, SEQ ID NO: 47, SEQ ID NO: 49, SEQ ID NO: 59, SEQ ID NO: 61, SEQ ID NO: 63, SEQ ID NO: 65, SEQ ID NO: 67, SEQ ID NO: 75, SEQ ID NO: 77, SEQ ID NO: 79, SEQ ID NO: 83, SEQ ID NO: 85, SEQ ID NO: 113, SEQ ID NO: 131 or SEQ ID NO: 133,
- b) nucleic acid sequences which, as the result of the degeneracy of the genetic code, can be derived from the amino acid sequence shown in

- 5 SEQ ID NO: 44, SEQ ID NO: 46, SEQ ID NO: 48, SEQ ID NO: 50, SEQ ID NO: 60, SEQ ID NO: 62, SEQ ID NO: 64, SEQ ID NO: 66, SEQ ID NO: 68, SEQ ID NO: 76, SEQ ID NO: 78, SEQ ID NO: 80, SEQ ID NO: 84, SEQ ID NO: 86, SEQ ID NO: 114, SEQ ID NO: 132 or SEQ ID NO: 134, or
- 10 c) derivatives of the nucleic acid sequence shown in SEQ ID NO: 43, SEQ ID NO: 45, SEQ ID NO: 47, SEQ ID NO: 49, SEQ ID NO: 59, SEQ ID NO: 61, SEQ ID NO: 63, SEQ ID NO: 65, SEQ ID NO: 67, SEQ ID NO: 75, SEQ ID NO: 77, SEQ ID NO: 79, SEQ ID NO: 83, SEQ ID NO: 85, SEQ ID NO: 113, SEQ ID NO: 131 or SEQ ID NO: 133 which encode polypeptides with at least 40% homology at the amino acid level with SEQ ID NO: 44, SEQ ID NO: 46, SEQ ID NO: 48, SEQ ID NO: 50, SEQ ID NO: 60, SEQ ID NO: 62, SEQ ID NO: 64, SEQ ID NO: 66, SEQ ID NO: 68, SEQ ID NO: 76, SEQ ID NO: 78, SEQ ID NO: 80, SEQ ID NO: 84, SEQ ID NO: 86, SEQ ID NO: 114, SEQ ID NO: 132 or SEQ ID NO: 134 and which have $\Delta 5$ -elongase activity.
- 15
19. An isolated nucleic acid sequence which encodes a polypeptide with $\Delta 6$ -elongase activity selected from the group consisting of:
- 20 a) a nucleic acid sequence with the sequence shown in SEQ ID NO: 69, SEQ ID NO: 81, SEQ ID NO: 111 or SEQ ID NO: 11183,
- b) nucleic acid sequences which, as a result of the degeneracy of the genetic code, can be derived from the amino acid sequence shown in SEQ ID NO: 70, SEQ ID NO: 82, SEQ ID NO: 112 or SEQ ID NO: 11284, or
- 25 c) derivatives of the nucleic acid sequence shown in SEQ ID NO: 69, SEQ ID NO: 81, SEQ ID NO: 111 or SEQ ID NO: 111 183 which encode polypeptides with at least 40% homology at the amino acid level with SEQ ID NO: 70, SEQ ID NO: 82, SEQ ID NO: 112 or SEQ ID NO: 112 184 and which have $\Delta 6$ -elongase activity.
- 30 20. An isolated nucleic acid sequence which encodes a polypeptide with $\omega 3$ -desaturase activity, selected from the group consisting of:
- a) a nucleic acid sequence with the sequence shown in SEQ ID NO: 87 or SEQ ID NO: 105,
- 35 b) nucleic acid sequences which, as a result of the degeneracy of the genetic code, can be derived from the amino acid sequence shown in SEQ ID NO: 88 or SEQ ID NO: 106, or

- c) derivatives of the nucleic acid sequence shown in SEQ ID NO: 87 or SEQ ID NO: 105 which have polypeptides with at least 60% identity at the amino acid level with SEQ ID NO: 88 or SEQ ID NO: 106 and which have ω 3-desaturase activity.

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21. An isolated nucleic acid sequence which encodes a polypeptide with Δ 6-desaturase activity, selected from the group consisting of:

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- a) a nucleic acid sequence with the sequence shown in SEQ ID NO: 89 or in SEQ ID NO: 97,

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- b) nucleic acid sequences which, as the result of the degeneracy of the genetic code, can be derived from the amino acid sequence shown in SEQ ID NO: 90 or in SEQ ID NO: 98, or

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- c) derivatives of the nucleic acid sequence shown in SEQ ID NO: 89 or in SEQ ID NO: 97 which encode polypeptides with at least 40% homology at the amino acid level with SEQ ID NO: 90 or in SEQ ID NO: 98 and which have Δ 6-desaturase activity.

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22. An isolated nucleic acid sequence which encodes a polypeptide with Δ 5-desaturase activity, selected from the group consisting of:

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- a) a nucleic acid sequence with the sequence shown in SEQ ID NO: 91, SEQ ID NO: 93, SEQ ID NO: 99 or in SEQ ID NO: 101,

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- b) nucleic acid sequences which, as the result of the degeneracy of the genetic code, can be derived from the amino acid sequence shown in SEQ ID NO: 92, SEQ ID NO: 94, SEQ ID NO: 100, or in SEQ ID NO: 102, or

- c) derivatives of the nucleic acid sequence shown in SEQ ID NO: 91, SEQ ID NO: 93, SEQ ID NO: 99 or in SEQ ID NO: 101 which encode polypeptides with at least 40% homology at the amino acid level with SEQ ID NO: 92, SEQ ID NO: 94, SEQ ID NO: 100, or in SEQ ID NO: 102 and which have Δ 5-desaturase activity.

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23. An isolated nucleic acid sequence which encodes a polypeptide with Δ 4-desaturase activity, selected from the group consisting of:

- 5
- a) a nucleic acid sequence with the sequence shown in SEQ ID NO: 95 or in SEQ ID NO: 103,
- b) nucleic acid sequences which, as the result of the degeneracy of the genetic code, can be derived from the amino acid sequence shown in SEQ ID NO: 96 or in SEQ ID NO: 104, or
- 10
- c) derivatives of the nucleic acid sequence shown in SEQ ID NO: 95 or in SEQ ID NO: 103 which encode polypeptides with at least 40% homology at the amino acid level with SEQ ID NO: 96 or in SEQ ID NO: 104 and which have $\Delta 4$ -desaturase activity.
- 15
24. An isolated nucleic acid sequence which encodes a polypeptide with $\Delta 12$ -desaturase activity, selected from the group consisting of:
- a) a nucleic acid sequence with the sequence shown in SEQ ID NO: 107 or in SEQ ID NO: 109, or
- 20
- b) nucleic acid sequences which, as the result of the degeneracy of the genetic code, can be derived from the amino acid sequence shown in SEQ ID NO: 108 or in SEQ ID NO: 110, or
- 25
- c) derivatives of the nucleic acid sequence shown in SEQ ID NO: 107 or in SEQ ID NO: 109 which encode polypeptides with at least 50% identity at the amino acid level with SEQ ID NO: 108 or in SEQ ID NO: 110 and which have $\Delta 12$ -desaturase activity.
- 30
25. The isolated nucleic acid sequence according to any of claims 16 to 24, which sequence is derived from an alga, a fungus, a microorganism, a plant or a nonhuman animal.
- 35
26. The isolated nucleic acid sequence according to any of claims 16 to 25, which sequence is derived from the order Salmoniformes, the diatom genera Thalassiosira or Cryptocodinium or from the family of the Prasinophyceae, Euglenaceae or Pythiaceae.
27. An amino acid sequence which is encoded by an isolated nucleic acid sequence according to any of claims 16 to 26.

28. A gene construct comprising an isolated nucleic acid according to any of claims 16 to 26, wherein the nucleic acid is linked operably with one or more regulatory signals.
- 5 29. The gene construct according to claim 28, wherein the nucleic acid construct comprises additional biosynthesis genes of the fatty acid or lipid metabolism selected from the group acyl-CoA dehydrogenase(s), acyl-ACP [= acyl carrier protein] desaturase(s), acyl-ACP thioesterase(s), fatty acid acyltransferase(s), acyl-CoA:lysophospholipid acyltransferase(s), fatty acid synthase(s), fatty acid
10 hydroxylase(s), acetyl-coenzyme A carboxylase(s), acyl-coenzyme A oxidase(s), fatty acid desaturase(s), fatty acid acetylenases, lipxygenases, triacylglycerol lipases, allenoxide synthases, hydroperoxide lyases or fatty acid elongase(s).
- 15 30. The gene construct according to claim 28 or 29, wherein the nucleic acid construct comprises additional biosynthesis genes of the fatty acid or lipid metabolism selected from the group Δ 4-desaturase, Δ 5-desaturase, Δ 6-desaturase, Δ 8-desaturase, Δ 9-desaturase, Δ 12-desaturase, Δ 6-elongase or Δ 9-elongase.
- 20 31. A vector comprising a nucleic acid according to any of claims 16 to 26 or a gene construct according to any of claims 28 to 30.
32. A transgenic nonhuman organism, comprising at least one nucleic acid according to any of claims 16 to 26, a gene construct according to any of claims 28 to 30 or a vector according to claim 31.
- 25 33. The transgenic nonhuman organism according to claim 32, which organism is a microorganism, a nonhuman animal or a plant.
34. The transgenic nonhuman organism according to claim 32 or 33, which organism is a plant.